

Modeling changes in ocean biogeochemistry due to ocean acidification and climate change

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Improving the Assessment and Valuation of
Climate Change Impacts for Policy
and Regulatory Analysis

January 27-28, 2011

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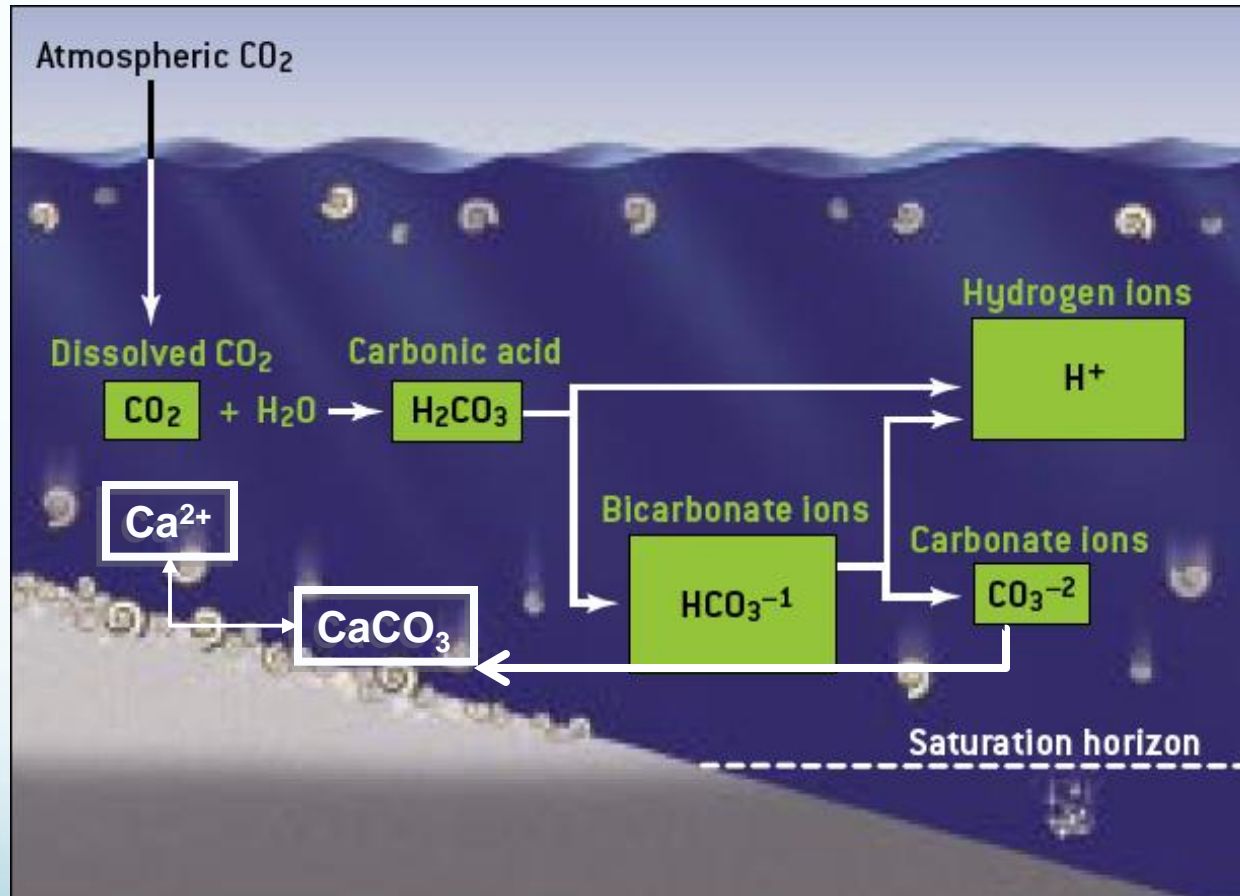
Capital Hilton, Washington, DC



Today's talk

- Chemistry & observations
 - What is OA? How well can we detect it?
- Earth system models
 - Ability to forecast future ocean conditions?
- Biological responses & models
 - How well can we forecast the future?
- Key knowledge gaps & needs

Rising CO_2 causes ocean acidification



Increasing CO_2

- Lowers pH
- Lowers $[\text{CO}_3^{2-}]$ saturation state “ Ω ”

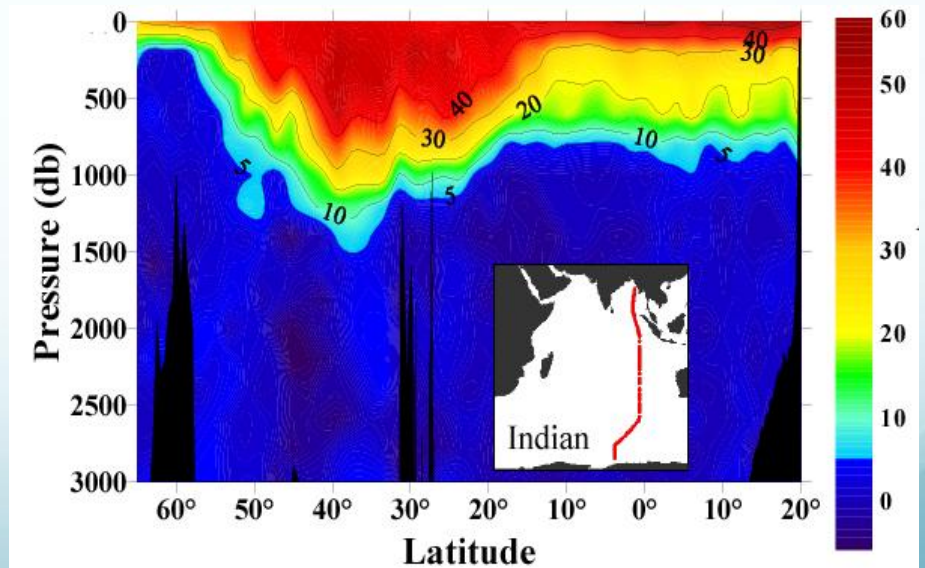
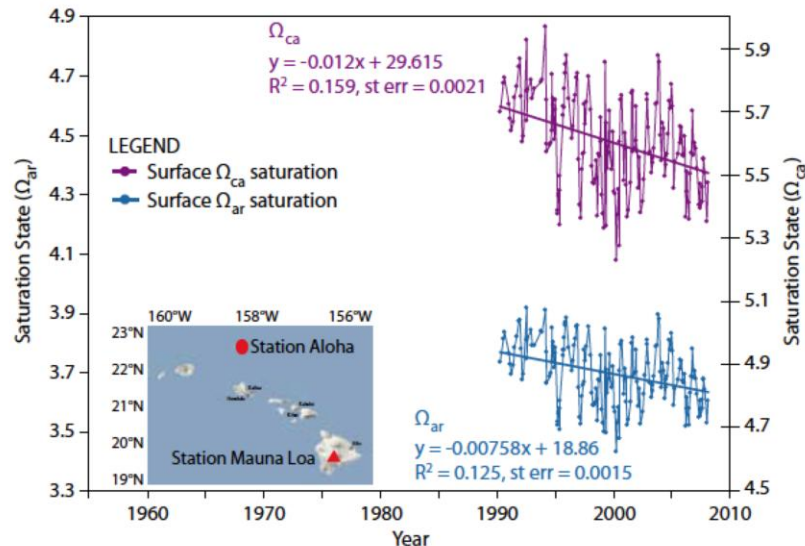
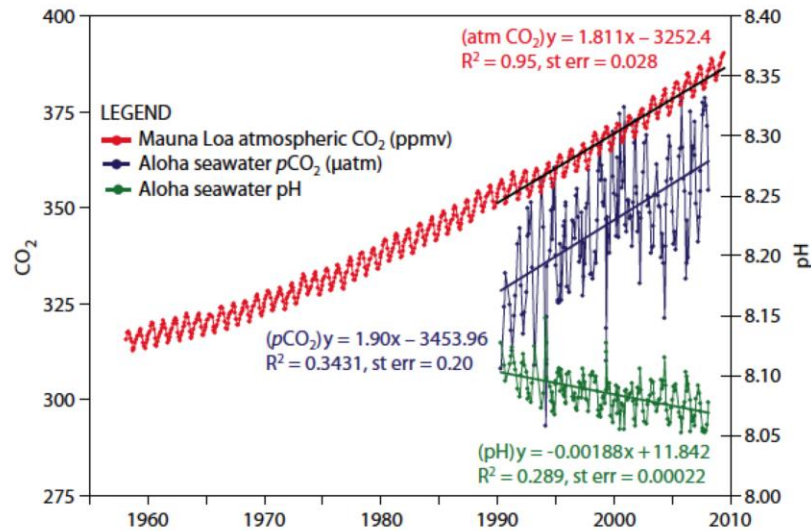
Present change is faster than rock weathering & other compensatory mechanisms

Observations show OA advancing

Now:

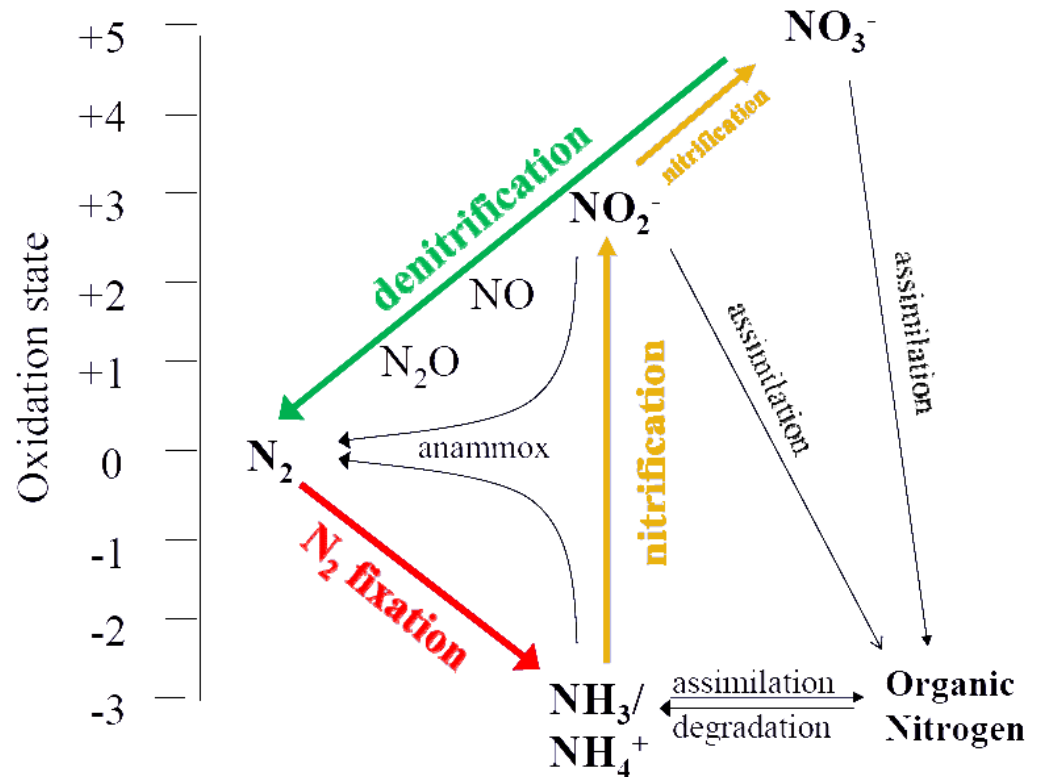
- ↑ Atmos. pCO₂
- ↑ Ocean pCO₂
- ↓ Ocean pH
- ↓ Calcite sat. st.
- ↓ Aragonite sat. st.
- ↑ Coastal variability

Anthropogenic CO₂ in upper ocean worldwide



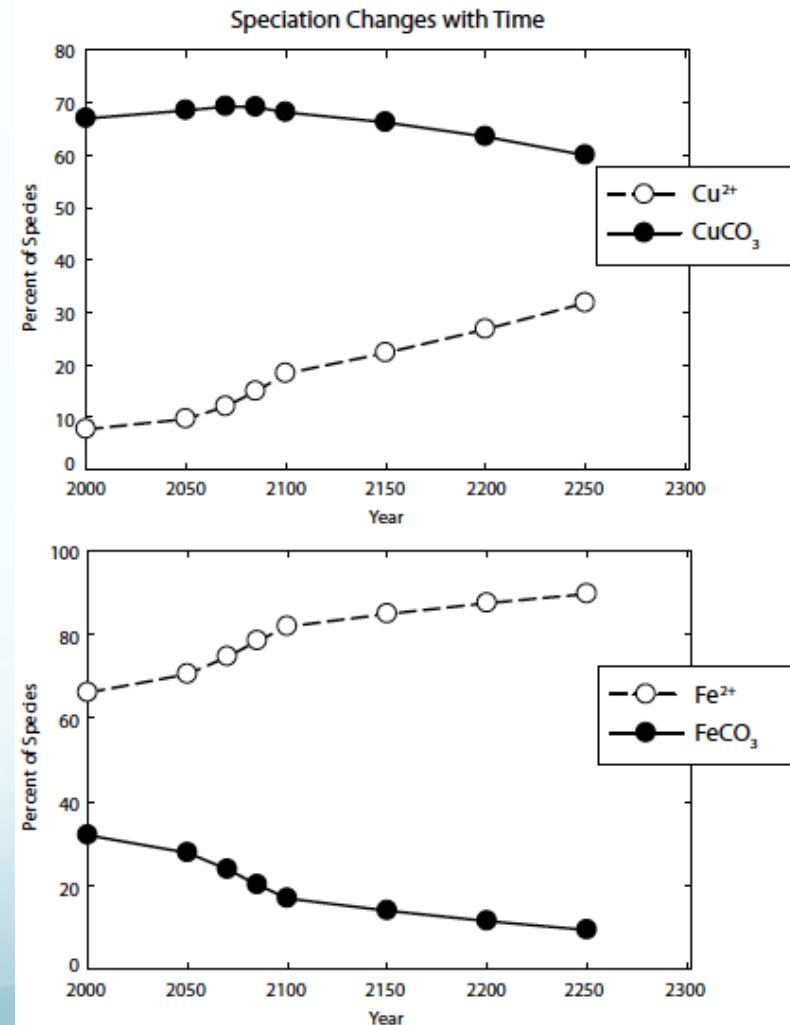
Other effects & synergies

- Marine nitrogen pool shifts towards ammonia as N_2 fixers thrive in a high- CO_2 ocean

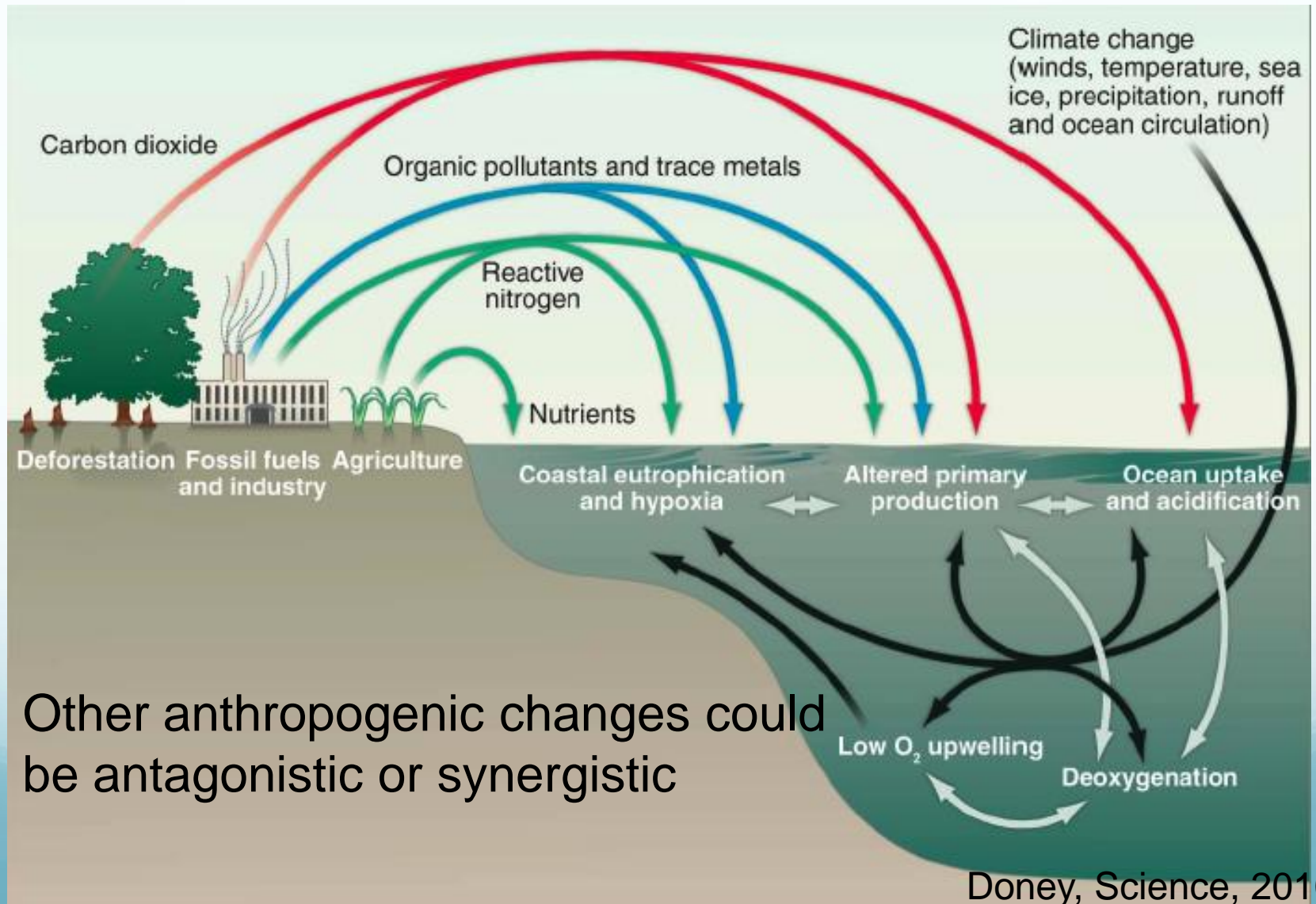


Other effects & synergies

- Metal ion speciation changes from changing pH and/or CO_2 :
 - Copper (Cu^{2+}) increases: toxic!
 - Iron (Fe^{2+}) increases: fertilizer?

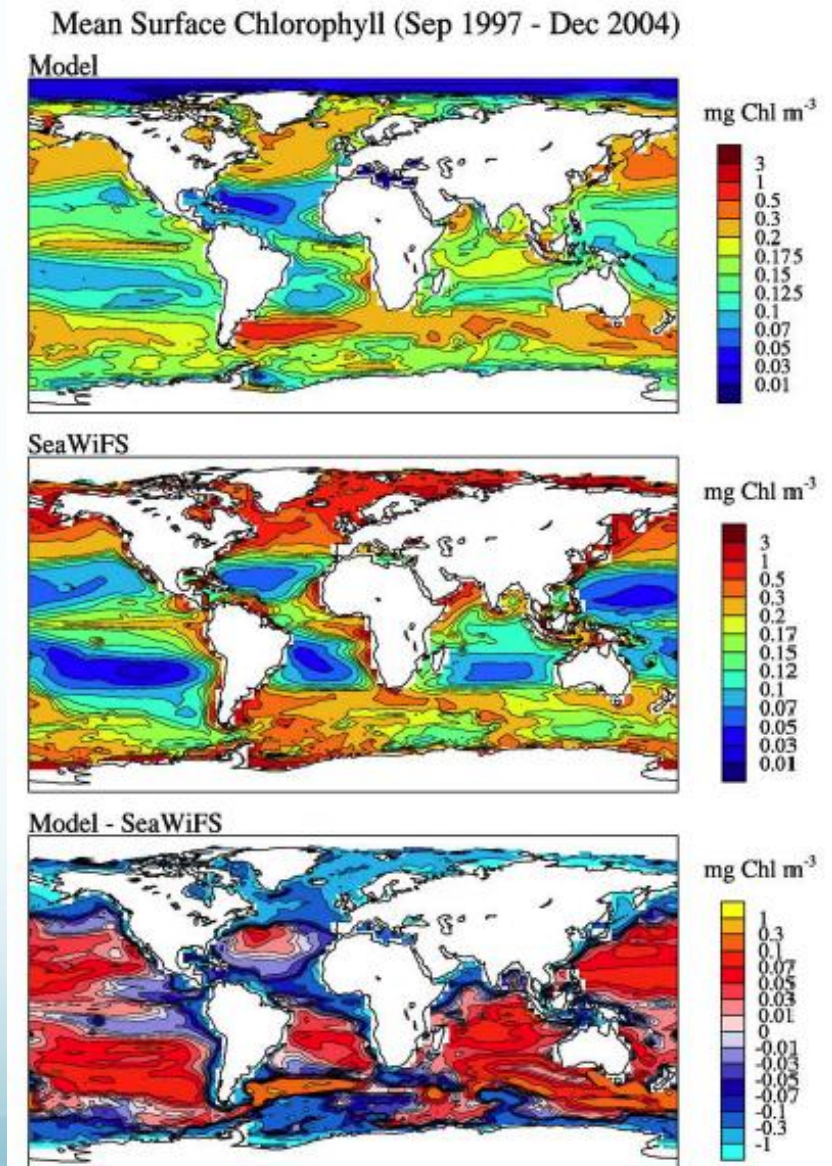


Other effects & synergies

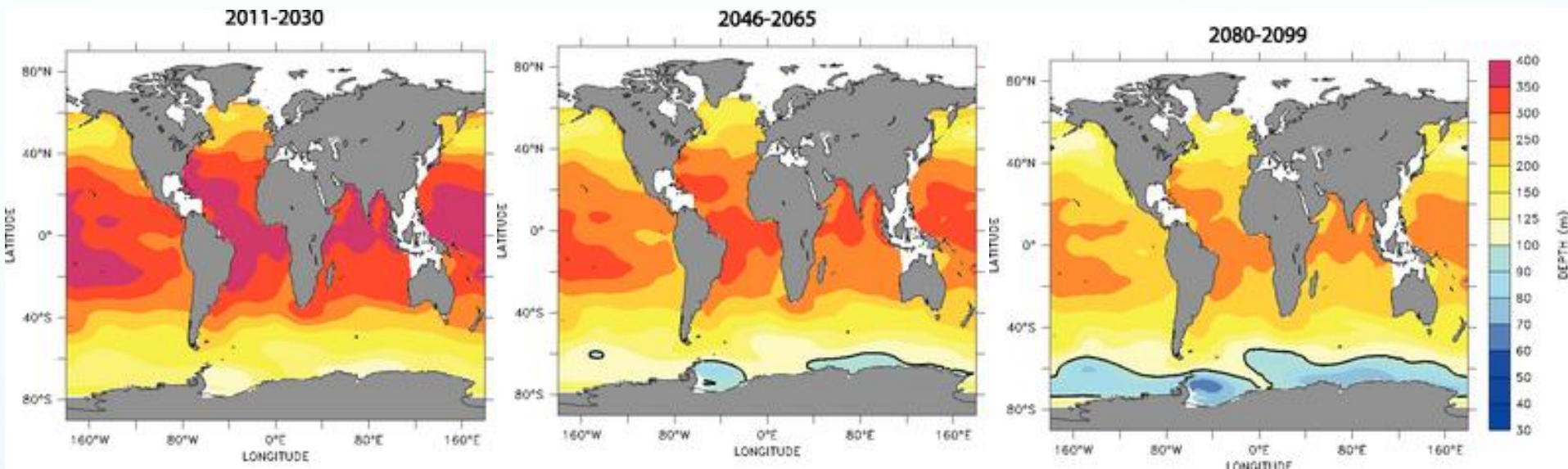


Earth system model simulations

- “Skill” evaluated with model-data comparisons of hindcasts
 - Simple & not-so-simple statistics
- Correct physics is key!
- BGC parameterizations are under continuous improvement



Model intercomparison used to create, evaluate forecasts



Multi-model median of % saturation of carbonate ion from OCMIP-2 models:
broad agreement that ocean pH and carbonate ion levels will decline in
response to rising atmospheric CO₂.

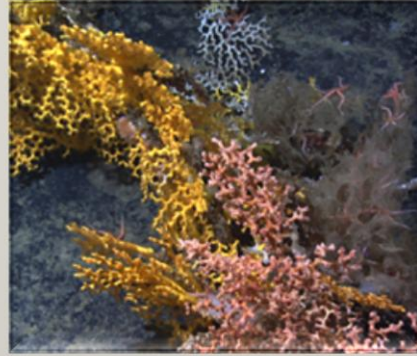
Key question: what will CO_{2,atm} be?

Biological Groups at Risk

Known



Warm-water corals



Cold-water corals

Some plankton



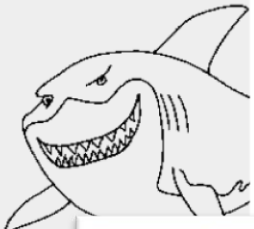
Pteropods



Many mollusks



Anticipated



Marine predators



Reef communities



Coastal environments



Fishermen

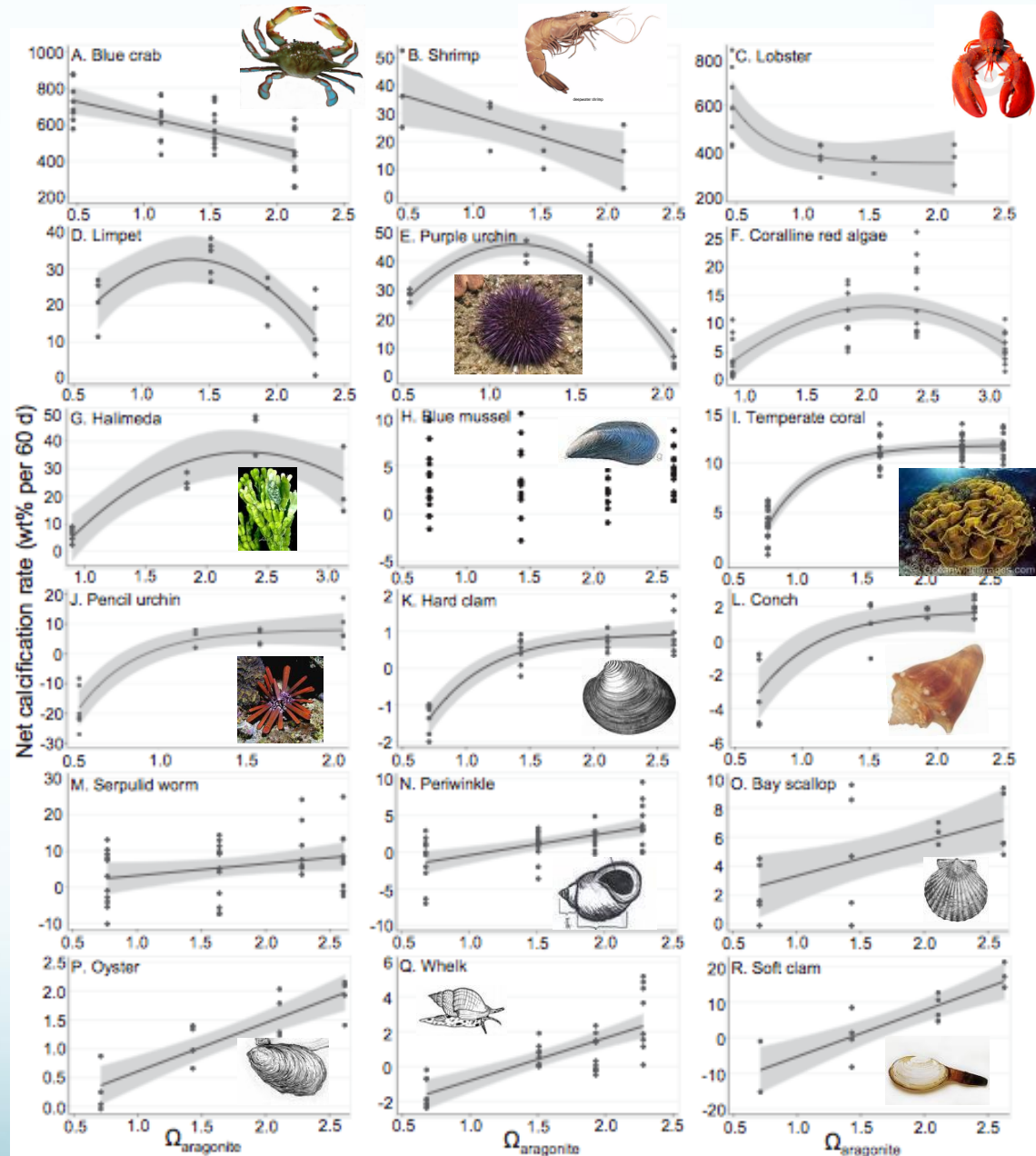


Businesses

Calcification responses vary

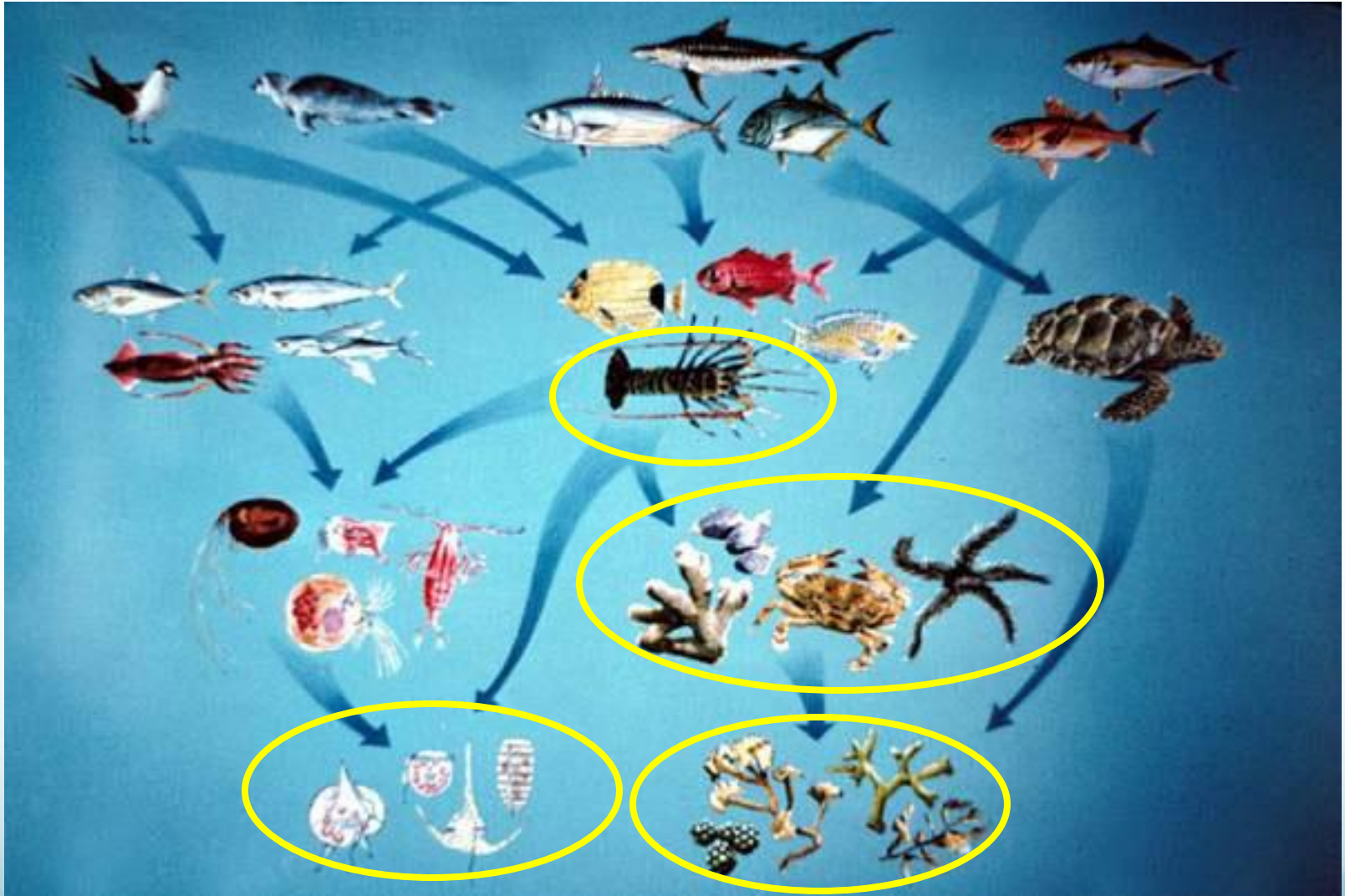
With decreasing Ω ,

- Crustaceans \uparrow
- Urchins, some algae, corals \downarrow
- Mollusks \downarrow
- Individual & population implications not yet understood



Saturation state

Ecological implications



Food web effects of OA are unknown, could be extensive

Ecosystem changes

In a coastal lagoon,
noncalcifiers replaced
many calcifiers over an
8-y. pH decline
(8.41-7.99)
(Wootton et al. PNAS 2008)



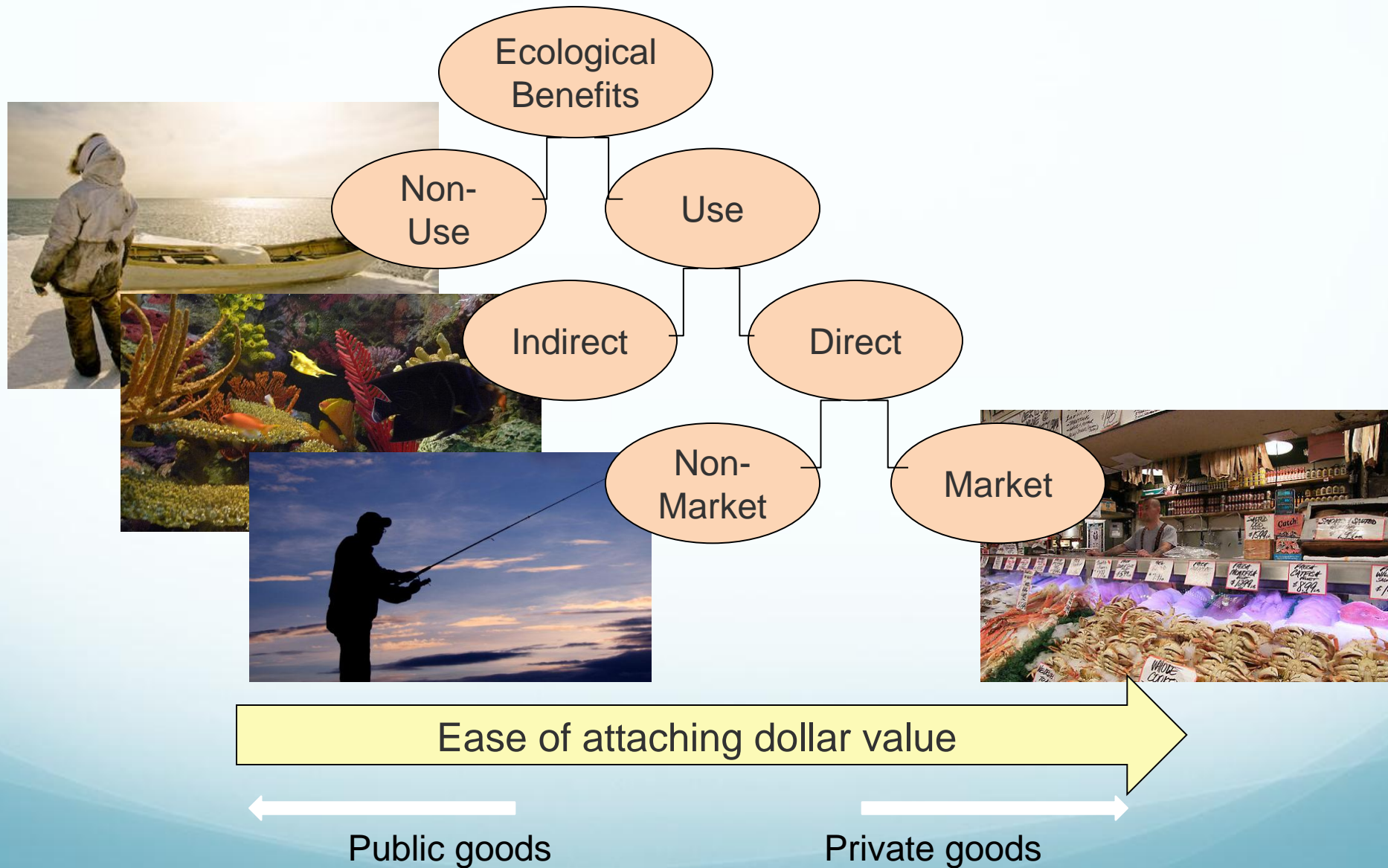
Photo, U. Washington

Near a volcanic CO₂ vent,
•adult mollusks damaged
•juvenile mollusks absent
•corals, coralline algae
absent



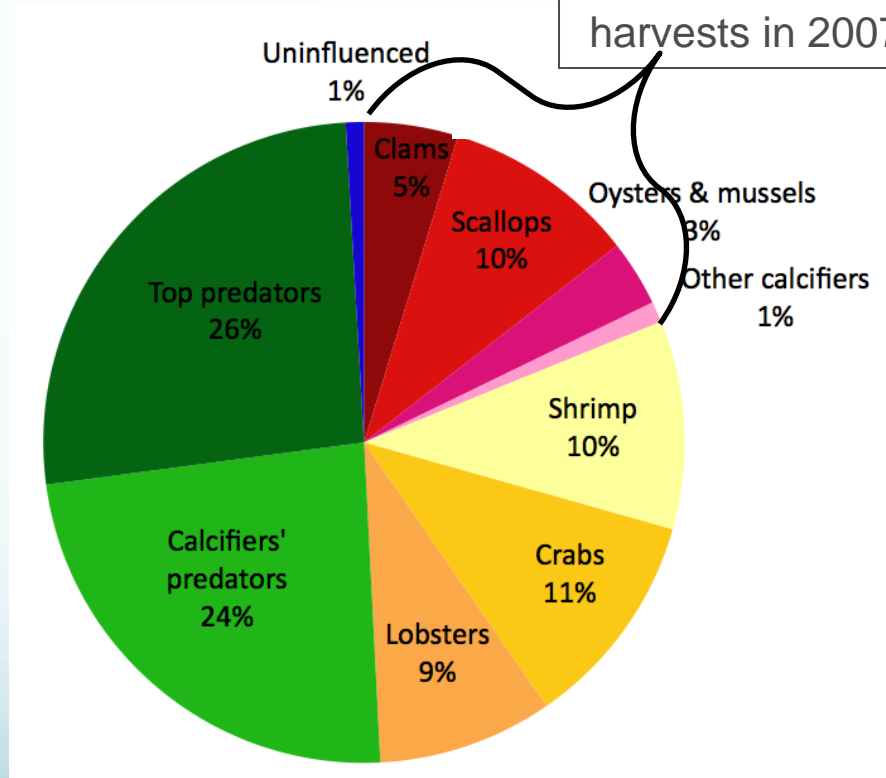
Hall-Spencer et al., Nature 2008

How to value ecosystem services?

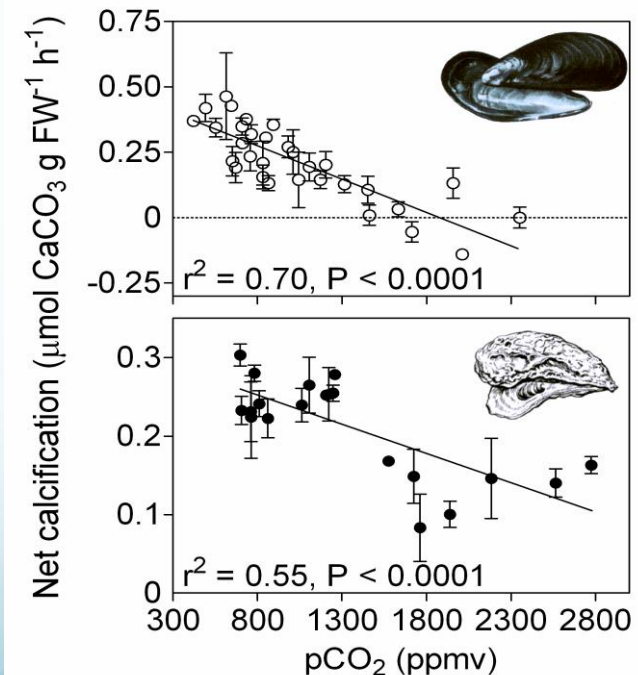


OA's economic impacts

U.S. mollusk harvests



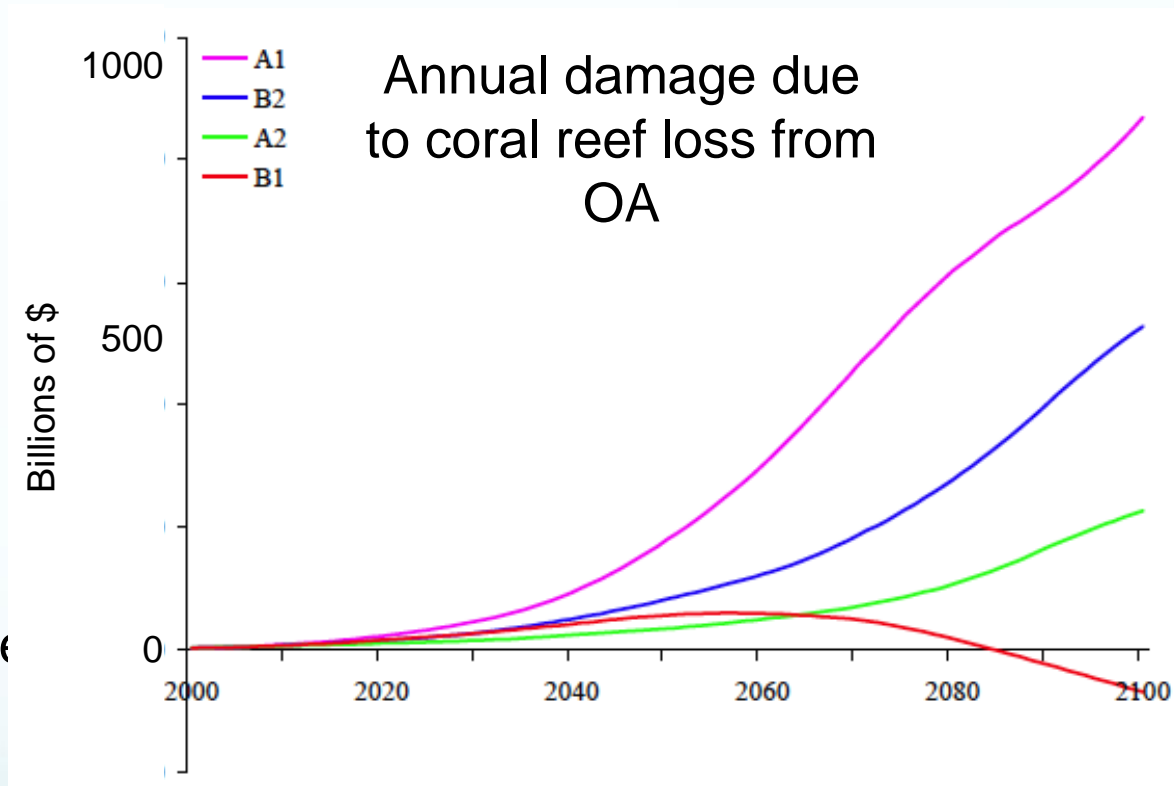
- Assume a 0.1-0.2 unit pH decrease by 2060 = 6-25% lower harvests
 - Annual losses of \$75-187M
 - NPV losses through 2060 of \$1.7-10B



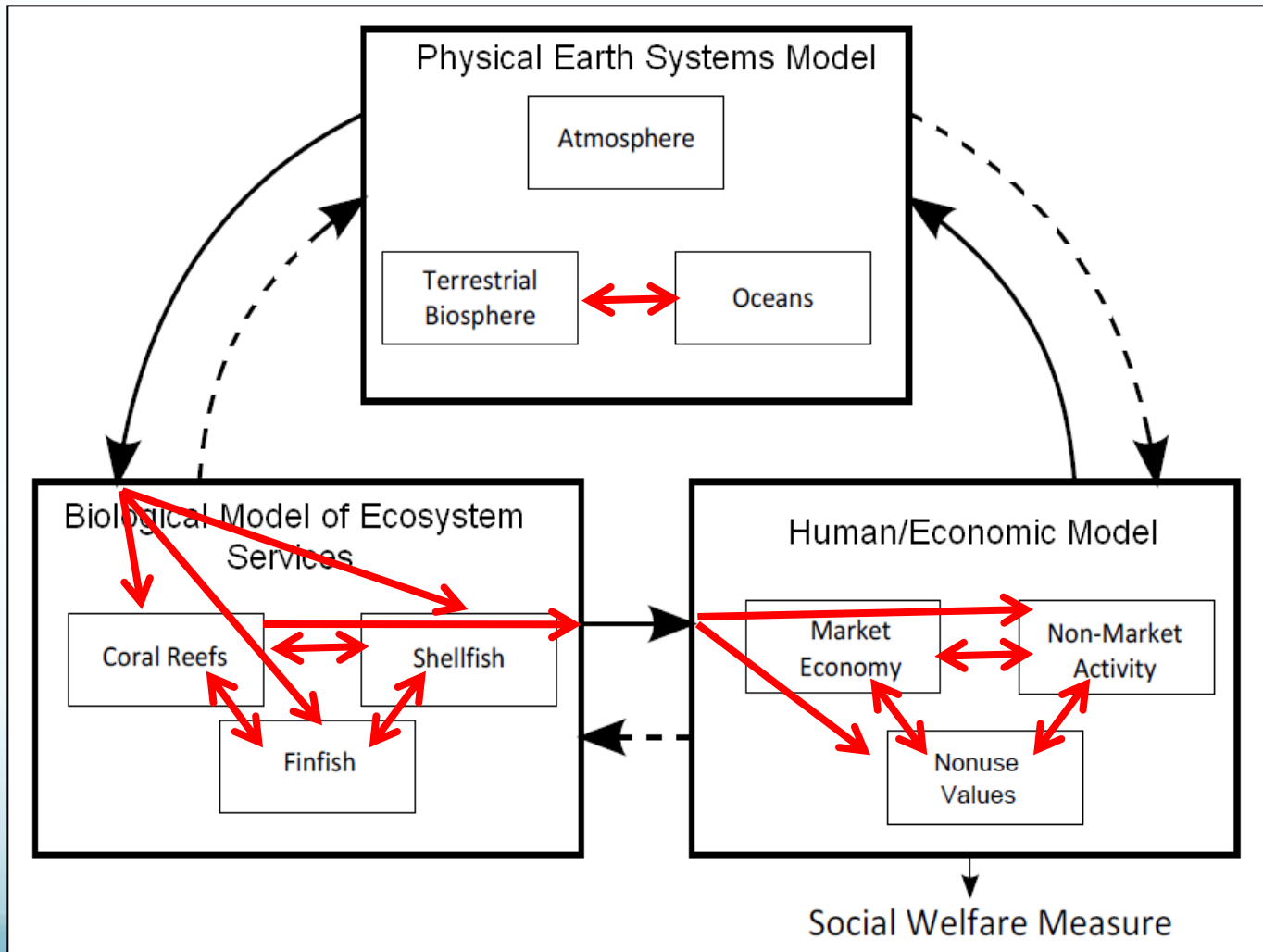
OA's economic impacts

Coral reefs

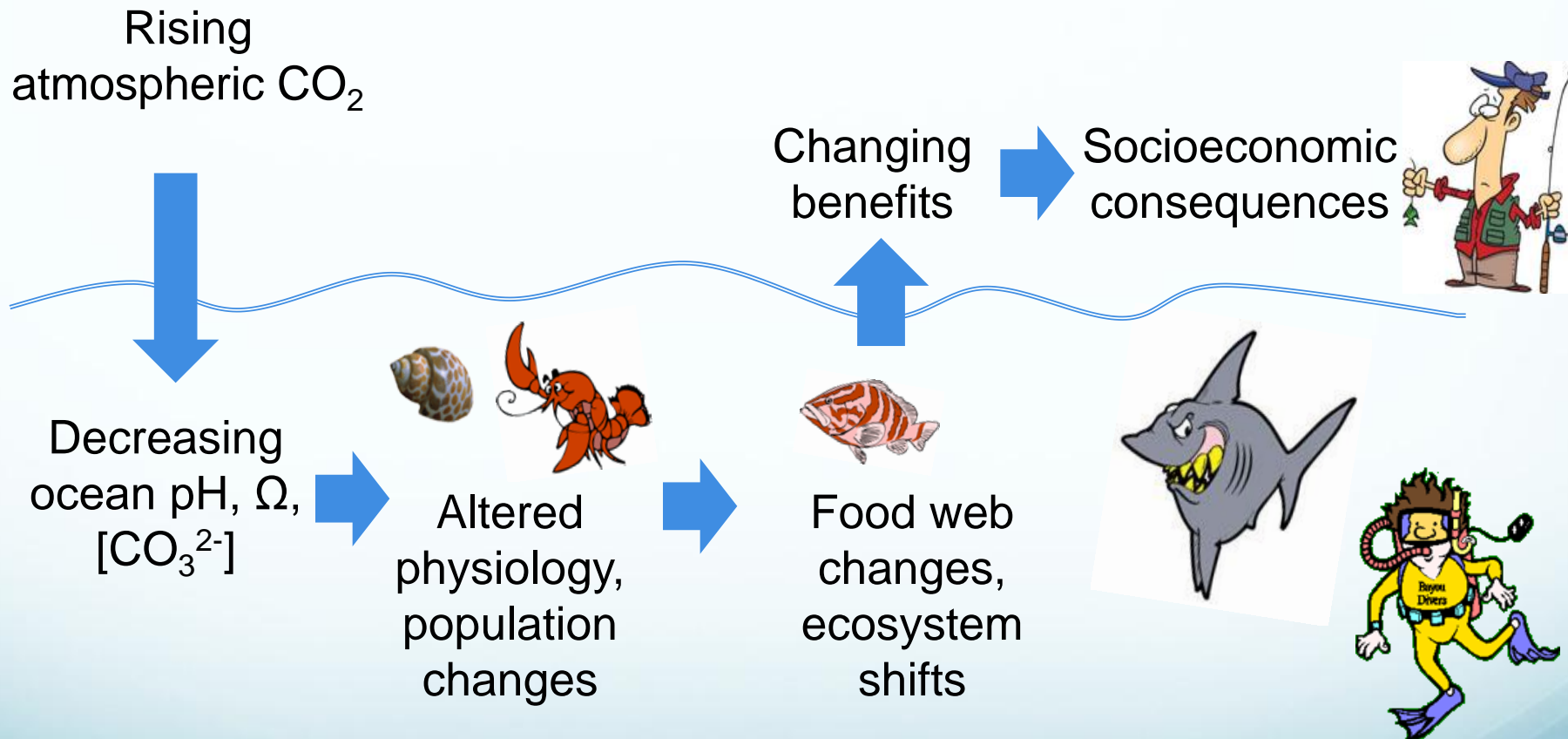
- Value coral reefs via meta-regression
- More information needed on relation of coral cover to OA
- Results strongly driven by importance of reefs for tourism – nonmarket services underestimated?



Knowledge gaps for OA IAM



Uncertainty builds



Certainty scorecard

	Certainty	Data limited?	Methods limited?
Atmospheric CO2 rising	High		
Ocean pH, carbonate decreasing	High	✓	
Marine organisms affected	Medium	✓	✓
Ecosystems change	Medium/Low	✓	✓
Ecosystem services change	Low	✓	✓
Socioeconomic consequences	Low	✓	✓